Can Hardwoods Be Eradicated From Pine Sites?

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Abstract. Intensive mechanical and chemical treatments were used annually for 12 years to eradicate hardwoods from a selectively managed loblolly (Pinus taeda *L.)/shortleaf* (P. echinata *Mill.) pine stand in south Arkansas. Although temporarily effective, a succession of indigenous shrubs and trees followed the cessation of eradication treatments. Improved pine diameter distribution from natural regeneration and an increase in radial growth of overstory pines were the benefits of this temporary hardwood eradication.*

The southern pines constitute an important commercial crop, and with proper management their rapid growth insures a renewable resource for the southern United States. On upland pine sites, hardwood shrubs and trees, herbaceous plants, and woody vines all compete with the pines for sunlight, growing space, moisture, and nutrients. The loss in pine volume production that results from this competition has been estimated to be 25 percent in natural stands and 14 percent in plantations (Fitzgerald, Peevy, and Fender 1973).

In even-aged management, heavy equipment, nonselective herbicides, and prescribed burns are useful in preparing harvested areas for planting or seeding with pine. Intensive preplant site treatments generally retard hardwood growth or reinvasion until pines dominate the site.

For uneven-aged management and some even-aged systems that rely on natural pine reproduction, managers are more restricted in the types of hardwood control measures they employ. Heavy equipment, fire, and nonselective herbicides can damage the seed source and destroy advanced reproduction, thus delaying optimum pine stocking.

In 1951 a study (Reynolds 1956) was initiated on the Crossett Experimental Forest in south Arkansas in an upland loblolly/shortleaf pine stand to determine hardwood reinvasion associated with 12 years of annual eradication treatments. A broad array of chemical and mechanical treatments were used to eliminate all hardwood species. This paper evaluates the reinvasion of hardwoods 18 years after treatments were terminated and the apparent effect of those treatments on pine development and growth.

METHODS

Second-growth loblolly/shortleaf pine-hardwood stands developed on the Experimental Forest following a 1915 diameter limit cut that removed merchantable pines 12 inches d.b.h. and larger. Recurrent wildfires were prevalent until the 1930s when fire protection began.

The study area is on level terrain and has a Bude silt loam soil (Glossaquic Fragiudalf) with an impervious layer at 18 to 40 inches that impedes internal drainage. Site index for loblolly pine is 85 to 90 feet at 50 years.

The study was installed in a 40-acre compartment that was placed under the selection system of management in 1939. Beginning that year, merchantable pines were harvested as single trees or small groups on a nine-year cutting cycle. Regulation of pine harvest cuts was by volume control. Merchantable hardwoods were harvested from the compartment in 1939 and 1948. Residual hardwoods ≥4 inches d.b.h. were girdled in 1949.

In 1951, four 0.25-acre plots were randomly established on a 5-acre test area within the 40-acre compartment. Measurements were taken on 0.1-acre interior subplots. At the time of study initiation, plots averaged 8,020 board feet (International ¼-inch rule) of pine sawlogs per acre and had an understory of over 3,500 hardwood stems per acre. Merchantable pines ranged from 4 to 20 inches d.b.h. with a basal area of 54 square feet per acre. From 1951 through 1962 efforts were made to completely eradicate all hardwoods from the four study plots as follows:

(1) In the spring of 1951, all hardwoods ≥3.5 inches d.b.h. were mechanically girdled on the plots and within 0.25 mile of the test area to eliminate any source of new seed. Hardwoods 1.0 to 3.5 inches d.b.h. were cut and AMS (ammonium sulfamate) crystals applied to the V-notch stumps.

Hardwoods <1.0 inch d.b.h. were foliar sprayed with a water solution containing 2 pounds of 80-percent AMS per gallon. Treatments to stems <3.5 inches d.b.h. were made only on the 0.25-acre plots.

(2) In the spring of 1952, hardwood sprouts were foliar sprayed with a 2-percent AMS solution.

(3) Beginning in 1953 and continuing through the spring of 1962, all hardwood regrowth was annually grubbed from the plots by hand to determine if stems were from sprout or seedling origin.

(4) In the spring of 1957, natural pine regeneration on the plots was mechanically thinned by cutting 10-foot swaths alternating with uncut strips of the same width to facilitate the location and growth of hardwood seedlings and sprouts.

(5) In July 1959, a heavy ground cover of vines, briars, grass, and weeds was sprayed with 2 pounds (a.e.) 2,4,5-T per acre using diesel oil as a carrier.

(6) In the fall of 1960, 2,4,5-T in diesel oil was injected into hardwoods of seed-bearing size on areas surrounding the plots.

Other than a cycle-harvest cut over the entire 40-acre compartment in 1966, there was no disturbance to the area from 1962 until 1980. In 1979 the original corners of 0.1-acre interior subplots were relocated on each of the four treated plots and a 100-percent inventory of woody stems was conducted in May 1980. Understory inventories were achieved by progressively covering 6-foot-wide transects across each plot.

Total heights of woody stems ≤3.5 inches d.b.h. (understory) were measured to the nearest foot. Diameters of understory species were measured to the nearest millimeter at a 0.5-foot height and

Table 1. Stocking of understory hardwood species during hardwood eradication and 18 years after treatment.

Species	1951[a]	1956[b]		1962[c]		1980[d]
		Seedl.	Sprouts	Seedl.	Sprouts	
Trees	Stems/acre					
Red oaks, White oaks (*Quercus* spp.)	878	0	0	0	2	480, 150
Red maple (*Acer rubrum* L.)	—	0	18	0	0	262
Flowering dogwood (*Cornus florida* L.)	485	0	0	8	0	178
American holly (*Ilex opaca* Ait.)	0	0	0	0	0	65
Elm (*Ulmus* spp.)	—	0	22	2	10	58
Sassafras (*Sassafras albidum* [Nutt.] Nees.)	—	0	2	0	0	40
Blackgum (*Nyssa sylvatica* Marsh.)	1192	0	5	0	0	35
Persimmon (*Diospyros virginiana* L.)	—	0	20	0	5	28
Red mulberry (*Morus rubra* L.)	0	0	0	0	0	25
Black cherry (*Prunus serotina* Ehrh.)	0	0	0	0	0	15
Sweetgum (*Liquidambar styraciflua* L.)	665	0	2	0	2	12
Eastern hophornbeam (*Ostrya virginiana* [Mill.] K. Koch)	0	0	0	0	0	12
Chinkapin (*Castanea pumila* [L.] Mill.)	0	0	0	0	0	10
Hickory (*Carya* spp.)	105	0	0	0	0	3
Locust (*Gleditsia* spp.)	0	0	0	0	0	3
Others[e]	258	0	0	0	0	—
Subtotal	3583	0	69	10	19	1376
Shrubs and small trees						
Huckleberry (*Vaccinium* spp.)	—	—	—	—	—	1105
Shining sumac (*Rhus copallina* L.)	—	—	—	—	—	483
Yaupon (*Ilex vomitoria* Ait.)	—	—	—	—	—	225
American beautyberry (*Callicarpa americana* L.)	—	—	—	—	—	182
Downy serviceberry (*Amelanchier arborea* [Michx. f.] Fern.)	—	—	—	—	—	60
Hawthorn (*Crataegus* spp.)	—	—	—	—	—	30
Devil's-walkingstick (*Aralia spinosa* L.)	—	—	—	—	—	30
Swamp privet (*Forestiera acuminata* [Michx.] Poir.)	—	—	—	—	—	3
Subtotal	—	—	—	—	—	2118
Total of all hardwood species	3583	0	69	10	19	3494

[a] *Inventory prior to hardwood eradication treatments.*
[b] *After six years of annual hardwood eradication.*
[c] *After 11 years of annual hardwood eradication.*
[d] *Eighteen years after hardwood eradication ended.*
[e] *Not enumerated by species in 1951 but included persimmon, red maple, sassafras, and elm.*

were used to calculate cross-sectional area. For trees ≥3.6 inches d.b.h. (overstory), diameters were measured to the nearest 0.1 inch at 4.5 feet. These measurements were recorded by species.

Three criteria used to assess the importance of and differences between understory species in 1980 included:

$$\text{Relative basal area} = \frac{\text{Cross-sectional area at 0.5 foot for individual species}}{\text{Cross-sectional area at 0.5 foot for all species}} \times 100$$

$$\text{Relative abundance} = \frac{\text{Number of stems for individual species}}{\text{Number of stems for all species}} \times 100$$

$$\text{Relative height} = \frac{\text{Mean height for individual species}}{\text{Sum of mean heights for all species}} \times 100$$

These criteria were summed for each species to indicate the relative importance of one species when compared to the other species.

RESULTS AND DISCUSSION

Hardwood Eradication

Most hardwood stems inventoried at yearly intervals were from sprout rather than seedling origin. From 1954 through 1962 hardwood sprouts totaled about 1,000 stems per acre compared to only 27 hardwood seedlings per acre. During that eight-year period, four species (persimmon, elm, red maple, and blackgum) accounted for 80 percent of all sprouts. New seedlings were entirely from red maple, flowering dogwood, sassafras, or elm.

Although grubbing of roots was a laborious task, the treatment was clearly effective in reducing growth of sprouts from residual rootstock. Over 77 percent of all sprouts were counted prior to 1958 and generally declined in number from 1956 through 1962, when 19 sprouts per acre were inventoried (Table 1) or 72 percent less than the 69 sprouts found in 1956, midway through the course of treatments.

Figure 1. In May 1980, hardwood trees, shrubs, and vines had reinvaded plots following eradication attempts 18 years earlier.

Hardwood Reinvasion

One might expect that future competition from hardwoods in this pine stand would have been minimal after such intensive eradication efforts. However, lack of disturbance and time since disturbance permitted natural plant succession to proceed uninterrupted (Figure 1).

In 1980, there were 3,494 stems per acre that included 24 species-groups of woody plants in the understory (Table 1). Understory pines accounted for an additional 273 stems per acre. Of the total hardwood stems, 1,376 were potential overstory species that represented 38 percent of the hardwoods inventoried in 1951. In terms of species diversity, there was exceptional recovery by hardwoods just 18 years after eradication treatments ended.

The ten most predominant understory species in 1980, based on the summation of relative basal area, relative abundance, and relative height, are listed in Table 2. Pine was the only overstory species. In addition, its importance in the understory ranked higher than any other species. Although three hardwood tree species (red oak, red maple, and flowering dogwood) had prominent positions in the understory, six of the ten predominant species were shrubs.

Number of stems per acre and mean heights for the understory components were subdivided into seedlings (≤4 feet in height) and saplings (≥5 feet in height but <3.6 inches d.b.h.). In 1980, there were 2,259 hardwood seedlings per acre, with an average height of 2.3 feet, that represented 65 percent of all hardwood stocking. The 1,235 saplings per acre averaged 10.0 feet in height. Although the 1980 stocking of hardwood seedlings exceeded that of saplings, the opposite was true for understory pine. Pine seedlings averaged 10 per acre compared to 263 saplings per acre. Pine saplings averaged 20 feet in height, twice as tall as hardwood saplings, but the average height of pine seedlings was equal to that of hardwood seedlings. Without follow-up hardwood control and in the absence of cycle harvests of overstory pines, the understory is slowly reverting to hardwood domination.

The inability to completely eradicate hardwoods may have some advantages over long periods of time because of the interdependence of plants and animals in their natural environment. If management by man is excluded from pine sites of the southeastern Coastal Plain, natural plant succession eventually leads to a climax forest of mixed hardwoods (Quarterman and Keever 1962).

Stand Structure and Growth of Overstory Pines

Benefits from hardwood eradication were ultimately expressed in stand structure and pine growth. As hardwoods were eradicated, pines increased in number. Although pine seedlings were not inventoried, their presence was obvious (Figure 2).

Reynolds (1959) proposed a desired stand structure for a well-stocked, uneven-aged, loblolly/shortleaf pine stand being managed on a five-year cutting cycle for the production of high-quality sawtimber with pulpwood, poles, and pilings as secondary products (Figure 3). The typical inversed J-shaped distribution reflects a proportionately increasing number of trees as diameter decreases, so that replacements are readily available in the event of mortality or following harvest operations. In 1951, prior to hardwood control, the diameter distribution in the present study was deficient in number of stems in the 4- to 11-inch d.b.h. classes (Figure 3). By 1980, there was a substantial ingrowth in number of stems 4 to 11 inches d.b.h. that had become established 18 to 30 years earlier while hardwood eradication treatments were in progress.

In May 1980, increment cores were taken at d.b.h. from seven dominant pines on the hardwood eradication plots to determine the effect of treatment on radial growth. These seven pines averaged 21.3 inches d.b.h. and approximately 81 years in

Table 2. Ten predominant understory species in 1980 based on relative basal area, relative abundance, and relative height.

Species	: Relative importance as a percent of stand total
Pine (*Pinus* spp.)	23.7
Red oak (*Quercus* spp.)	10.9
Huckleberry (*Vaccinium* spp.)	10.6
Shining sumac (*Rhus copallina* L.)	7.7
Red maple (*Acer rubrum* L.)	5.9
Privet (*Forestiera acuminata* [Michx.] Poir.)	4.2
Yaupon (*Ilex vomitoria* Ait.)	3.2
Devil's-walkingstick (*Aralia spinosa* L.)	3.2
Flowering dogwood (*Cornus florida* L.)	3.1
American beautyberry (*Callicarpa americana* L.)	3.1
Total for all ten species	75.6

Figure 2. In May 1955, natural pine regeneration was well established on plots (foreground) where all hardwoods had been controlled annually since 1951.

age. During the 12 years prior to hardwood eradication (1939–50) these pines averaged 0.22 inch per year in diameter growth. That growth was significantly less (paired t-test at 10-percent level) than the 0.26 inch per year attained while treatments were in progress (1951–62). In south Arkansas, Grano (1970) found that 47- to 53-year-old loblolly/shortleaf pines on plots without understory hardwoods consistently outgrew those on control plots.

Diameter growth of loblolly pine in northeast Louisiana has been related to available soil moisture that is often depleted by late June, so that growth thereafter depends on the amount and distribution of rainfall (Moehring and Ralston 1967). In the present study, mean monthly precipitation from June through September totaled 16.50 inches for 1939–50 and 16.45 inches for 1951–62. Mean differences by analysis of variance were not significant at the 5-percent level. The mean yearly total for 1939–50 was 56.4 inches and for 1951–62 was 54.5 inches. Consequently, differences in pine radial growth between the two comparison periods do not appear to have been influenced by rainfall patterns.

Although thinning of overstory pines during normal management operations may have influenced diameter growth, more thinnings were made in the 12 years prior to study installation than during the 12 years the study was active. Scheduled cycle cuts were made within the 40-acre compartment during 1939 and 1948. In each cut an average of about 20 pines per acre were removed in a d.b.h. range from 4 to 25 inches. During 1957 a third cycle cut on the compartment removed an average of 30 pines per acre with d.b.h. between 4 and 29 inches, but there was no record of any pines being cut from study plots.

Basal area stocking for overstory pines in 1980 was over 100 square feet per acre compared to 54

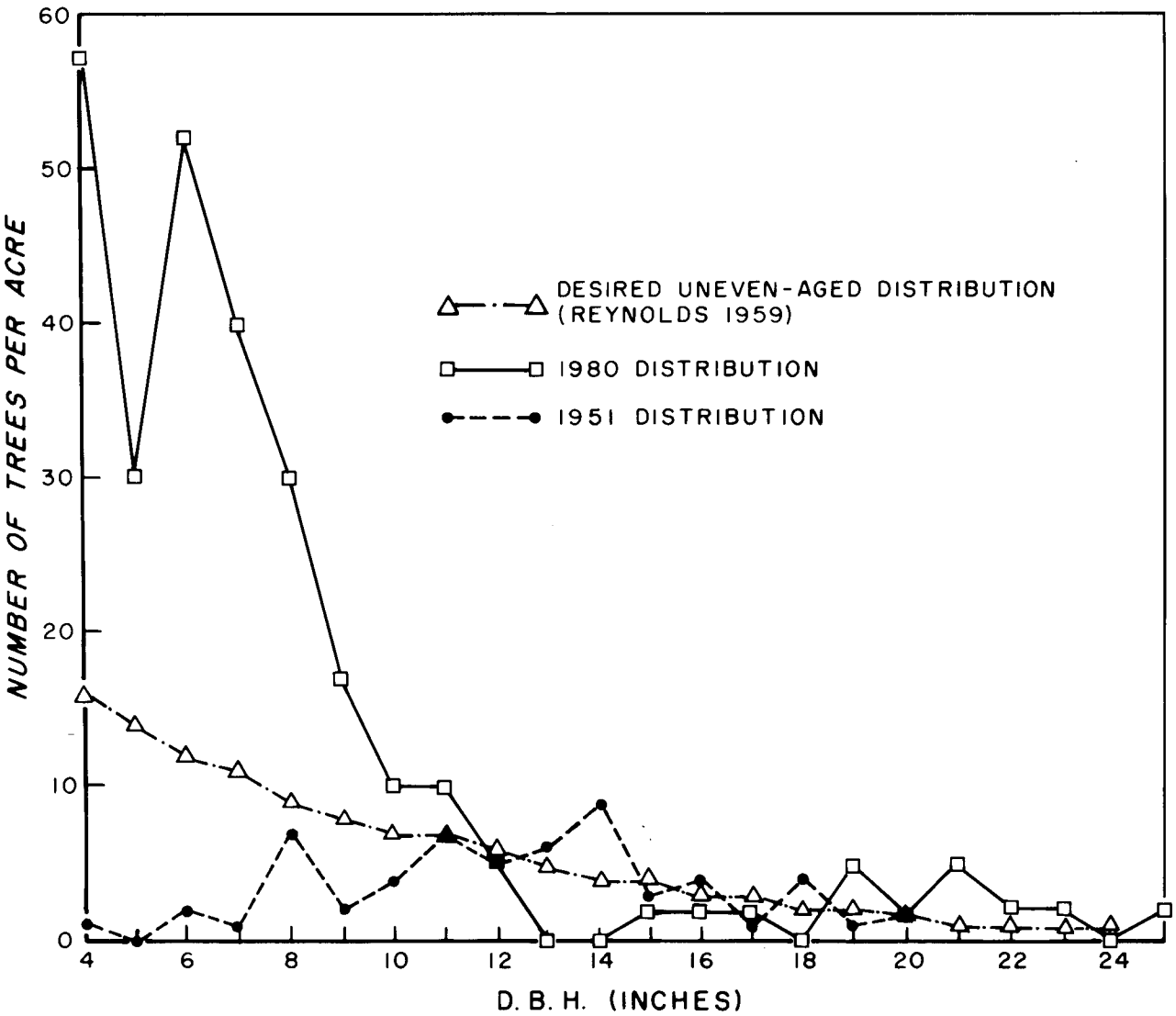

Figure 3. Actual and desired diameter distributions for merchantable pines in the hardwood eradication study.

square feet per acre in 1951. Sawlog volume on study plots in 1980 averaged 14,000 board feet per acre (International ¼-inch rule).

CONCLUSIONS

On a commercial basis it would be hard to justify the intensive hardwood control treatments applied in this study. However, the variety of treatments suggests the degree of disturbance that can be used in uneven-aged stands for controlling hardwoods while, at the same time, favoring pine management. Economically feasible methods of hardwood suppression are known to temporarily postpone hardwood reinvasion and subsequent development until faster-growing pines begin to dominate the site six or seven years after their establishment. But, short of soil sterilization, complete eradication of hardwoods is unachievable.

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